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length of, say, 200 feet, requiring in the case of the Newtonian a tube nearly this length, can be obtained by a tube of about 66 feet. In no other way could such a large primary image as a focal length of 200 feet would give be obtained, while retaining, say, 1° of the field. The image of the Moon would here be about 22 inches in diameter, with the above relation of curvature of surfaces, but this relation need not necessarily be adhered to, where, for the Sun or Moon, the aperture might be very much less than in the proportion given, as an increase in the curvature of the convex mirror produces a longer equivalent focal length; and as this can be done more easily as the aperture of the concave mirror is reduced, and the first angle made smaller, a much greater equivalent focal length could be obtained; and as I have shown, one foot of aperture is sufficient to give an image of the Moon when the equivalent focal length is 80 feet, a mirror of, say, 2 feet aperture and a slightly longer exposure, mounted on any of the very large refractors in existence, would easily give a much larger primary image—too large, perhaps, to photograph as a whole, but excellent for portions of such an object as the Moon.

The conditions I have given may not be the best to get the finest definition: probably they are not. It is easy to see that where there is a balancing process at work between the two mirrors, the angles of incidence and the place where the image is produced have an importance, as well as the curves of the mirrors. With a parabolic mirror and a spherical convex, the image is as it would be in the Cassegrain form, with these mirrors over-corrected. Whether it would be an advantage to reduce the amount of correction given to the concave mirror, to make it as if the focal length were to be the equivalent focal length; or whether it would be better to obtain this correction, as in the Cassegrain, by making the convex curve an hyperboloid, is yet to be seen. I am working at this, and hope to have something from trial; but, in view of the possibilities of this form of telescope, I hope that some competent person will take up the investigation of the theoretical conditions involved, so that the best can be made of this form of reflecting telescope.

Preliminary Note on the Determination of Terrestrial Longitudes by Photography. By Captain E. H. Hills, R.E.

The question of the practicability of some method for the determination of longitudes by means of photographs of the moon and stars is one that has engaged the attention of several experimenters.

It is one of great importance for the explorer and surveyor, the inaccuracy of the methods at present available being so great that they are practically never employed in the field.

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Among others Dr. Schlichter, in England, and Dr. Runge, in Germany, have worked at this subject. The latter attempted no great degree of accuracy, but directed his attention rather to the question of the possibility of obtaining a rough approximation by the use of an ordinary photographic camera and watch, than to the investigation of the maximum accuracy obtainable by using a suitable instrument. At the same time Dr. Runge was, I believe, the first to suggest that it was not at all necessary that the Moon and star exposures should be made at the same time. This, as will be seen, is an integral part of the method now brought before the Society.

Dr. Schlichter worked on the method of photographing the Moon and a bright star near it, and measuring the lunar distance on the plate. There seems no doubt that results can be obtained by this method far exceeding in accuracy any that can be obtained by the use of a sextant or theodolite. The principal objection to its general use seems to lie in the fact, that there would be very few nights in the year when it could be employed, unless the photographic plate were made to include a large angle, which would be undesirable for many reasons. It is also an objection to this method that the measurement of the angular distance between Moon and star involves a knowledge of the focal length of the lens, and that change of temperature would affect the result in a degree by no means negligible.

The present method is available any night that the Moon is visible, and the reductions involve a knowledge only of the approximate position of the optical centre of the plate, which change of focal length will not affect. It is as follows:

The camera is set up so that the image of the Moon is about the centre of the plate and a series of instantaneous exposures are made, allowing such an interval between the exposures that the Moon images on the plate will not overlap, *i.e.* from 1½ minutes to 2½ minutes according to the Moon's age.

After a set of, say seven, Moon exposures the camera is left untouched until bright stars of approximately the same declination as the Moon have arrived at the same point in the heavens. The camera is then opened for periods of one minute and the stars allowed to impress their trails on the plate. These star exposures would be repeated four or five times. It is immaterial whether the star or the Moon exposures be made first, and if found convenient two sets of star exposures may be made in order to get stars on both sides of the Moons.

It is obvious that if the L.M.T. of the Moon and star exposures be known such a plate gives all the data necessary for computing the Moon's R.A. at the time of each exposure, and hence the G.M.T. and longitude.

The camera employed was one specially designed for this work. It was made regardless of weight, and is somewhat heavy (55 lbs. including stand). This weight might, if thought advisable, be considerably reduced in a future pattern.

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The only two essentials are:

(1) Stability. A camera of this size, $19\frac{1}{2}$ inches focal length, in combination with a suitable micrometer, may be looked upon as an instrument reading to seconds of arc, and will require the same degree of stability. There is, however, this in favour of the camera, that it need not be touched from the first exposure to the last one, and the observer may remain at a distance of several feet from it, the exposures being made by a pneumatic shutter actuated by an india-rubber ball and tube; and this shutter may be placed on a separate stand.

(2) Means of adjusting the plate at right angles to the optical axis.

This is the only instrumental adjustment required, and is done as follows:—The sensitive plate in the dark slide is pressed up against three sharp-pointed screws, which puncture the gelatine film, and leave three points from which the position of the plate in the slide can be determined. To adjust and find the "centre" of the plate the camera is placed lens downward over a mercury bath, and a piece of plate glass placed in the position of the sensitive plate and levelled. Then that point on the plate which coincides with its reflected image is the point at which a perpendicular from the centre of the lens cuts the plate. The position of this point with reference to the points of the three screws being once found, it can be marked on the sensitive plate after exposure and development.

The lens used with this camera was a Dallmeyer Rapid Rectilinear, of $19\frac{1}{2}$ inches focal length.

The measurements were done with a micrometer reading to ·001 mm.

Two axes approximately at right angles, and approximately parallel and perpendicular to the meridian through the centre, were ruled on the plate with a needle, and the coordinates measured from these. The semidiameter of the Moon images was measured on the plate, so that coordinates of the Moon's centre were obtained.

The method employed for reducing the measurements is that worked out by Professor H. H. Turner for reducing the Astrographic Chart plates. (See *Monthly Notices*, *R.A.S.*, November 1893.) The R.A. and N.P.D. of the centre can be found by any approximate method; it will suffice if they are correct within a few minutes of arc.

No small part of the success of this as a practical, working method of longitude determination is due to these elegant and convenient formulæ, without the aid of which the computation of a plate would be most laborious.

The two plates, of which the results are given below, were exposed at the Royal Engineer Observatory, Chatham, on the

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night of 1894 October 16. In these first experiments the camera was placed on a solid masonry pier. In each case seven Moon exposures were made, and *Jupiter* and *Aldebaran* were used as reference stars. The times were taken with the Observatory clock, transits being taken as opportunity offered.

Any error in time will produce the same error in the resulting longitude, but it is evident that any error in the assumed clock rate will, by affecting the scale of R.A. on the plate, produce a similar error in the Moon's R.A., and hence a large error in the longitude.

The following tables show the longitude as worked from these two plates :

PLATE 1.

	Longitude.	
	m	s
Moon 1	1	59·4
2	2	4·8
3	2	3·5
4	2	12·7
5	2	13·1
6	2	7·8
7	2	8·2
Mean	2	7·07

PLATE 2.

	Longitude.	
	m	s
Moon 1	2	4·2
2	2	8·3
3	2	8·1
4	2	12·0
5	2	6·1
6	2	7·8
7	2	6·7
Mean	2	7·60

The true longitude was $2^{\mathrm{m}}\,8^{\mathrm{s}}{\cdot}13$, and the errors of these two determinations were, therefore, $1^{\mathrm{s}}{\cdot}06$ and $0^{\mathrm{s}}{\cdot}53$ respectively.

The principal source of error that this method is liable to, is the difference in refraction, owing to the different states of the atmosphere at the times of the Moon and star exposures. This error will disappear if the photograph be taken on or near the meridian, because in that case a change in apparent altitude will not affect the Moon's R.A. as measured from the plate. It is noteworthy that of the two plates, given above, No. 2 was exposed on the meridian, whereas in the case of No. 1 the Moon was some three hours from the meridian. It may be only an accidental coincidence that the result of No. 2 has only half the error of that of No. 1, but there is no doubt that the conditions for maximum accuracy are to expose near the meridian, unless there are stars in such a favourable position that only a short interval is necessary between the two sets of exposures.

It is, of course, essential that more plates should be exposed in order to gain further experience of the method, but it seems reasonable to suppose that this will result in increased accuracy being obtained, and even as the results stand now they are many times more accurate than could be obtained by any other method with a portable instrument.

Note.—The condition given above as regards exposure on the meridian being essential for obtaining the maximum accuracy is

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only correct if the Moon's R.A. is used in finding the longitude, as was the case with the plates of which the results are given above. Professor Turner has pointed out that if the Moon's place be left in standard coordinates, and not converted into R.A., it is possible so to select the coordinate axes that the refraction error would be eliminated in all cases.

Notes on Suitable Stations in Norway for Viewing the Total Eclipse of the Sun on 1896 *August* 8. By Colonel A. Burton-Brown, R.A., F.G.S.

It having come to my knowledge that some doubts had arisen as to the suitability of Norway as a post of observation for the total eclipse of the Sun in 1896, and having had both experience in total eclipse expeditions and of travelling in Norway, I thought I could not do better than spend my summer holiday in obtaining information that might be useful to Fellows of this Society and astronomers generally. Accordingly, I determined to make a special tour of observation both to the west coast, and also to Finmarken, Lapland, and the Russian frontier on the east coast. It was clear to me that some notes that had been published on the subject entered somewhat into the region of speculation, and might possibly in such an exceptional country as Norway, broken up into mountains and fjords, and where it was difficult to get trustworthy maps or guides, result in disappointment. Having, therefore, arranged to spend some weeks on this work, I started early in June for Trondhjem and the North, and have now the pleasure of laying before the Society the result of my observations. Since my return, in order to compile a suitable map to illustrate this paper, I wished to verify certain astronomical work, and I desire to express my thanks to Professor Turner and to Mr. A. C. D Crommelin for useful notes and calculations, and in a very large measure to Captain Wesfel, of the Norwegian Artillery, who accompanied me in my journey through Finmarken, and whose knowledge of Lappish and Russian enabled me to penetrate far up the Tana River and other out-of-the-way parts amongst the Finns. My own knowledge of the languages, and of Laplanders' and Norwegian manners and customs, also stood me in good stead. I had previously found that on travelling out of the beaten track very little dependence can be placed on guide-books—even the usually reliable Baedeker is full of errors—and this made me more anxious that astronomers taking part in this expedition, especially as some of the posts would be found in isolated and more or less un-get-at-able spots and difficult of communication, should not be led astray in this matter. Statements having approximate truth may be good enough for ordinary tourists, but yet utterly insufficient for the careful work of an observer of an eclipse expedition.